

# EBERSWALDE DELTA & The Fluvial Environment in the Holden Region during the Noachian-Hesperian Transition

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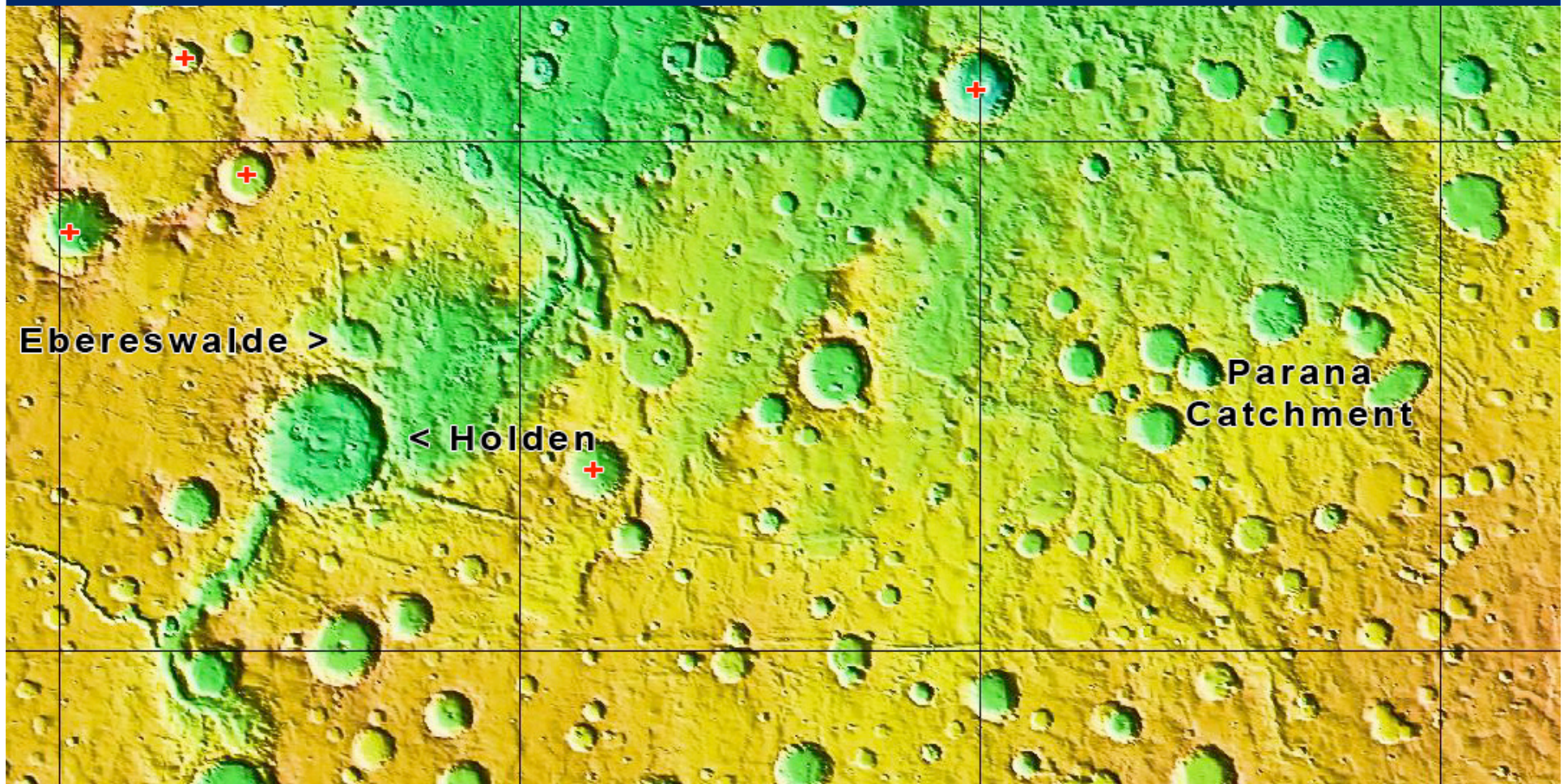
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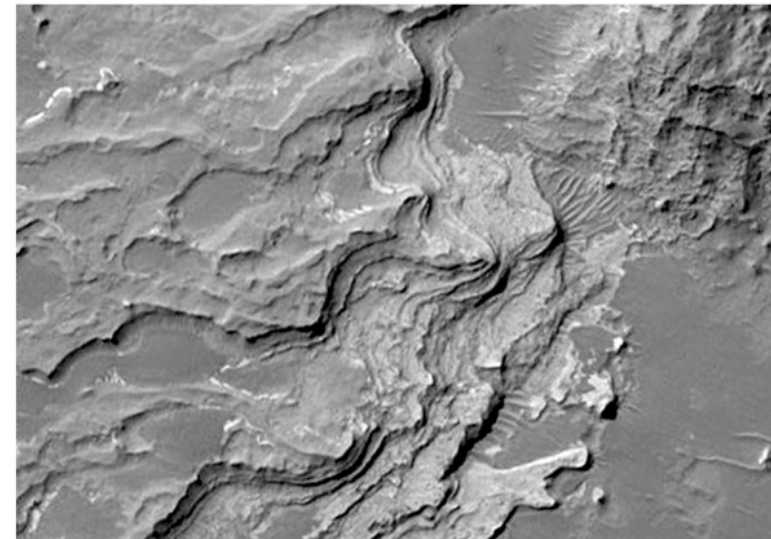
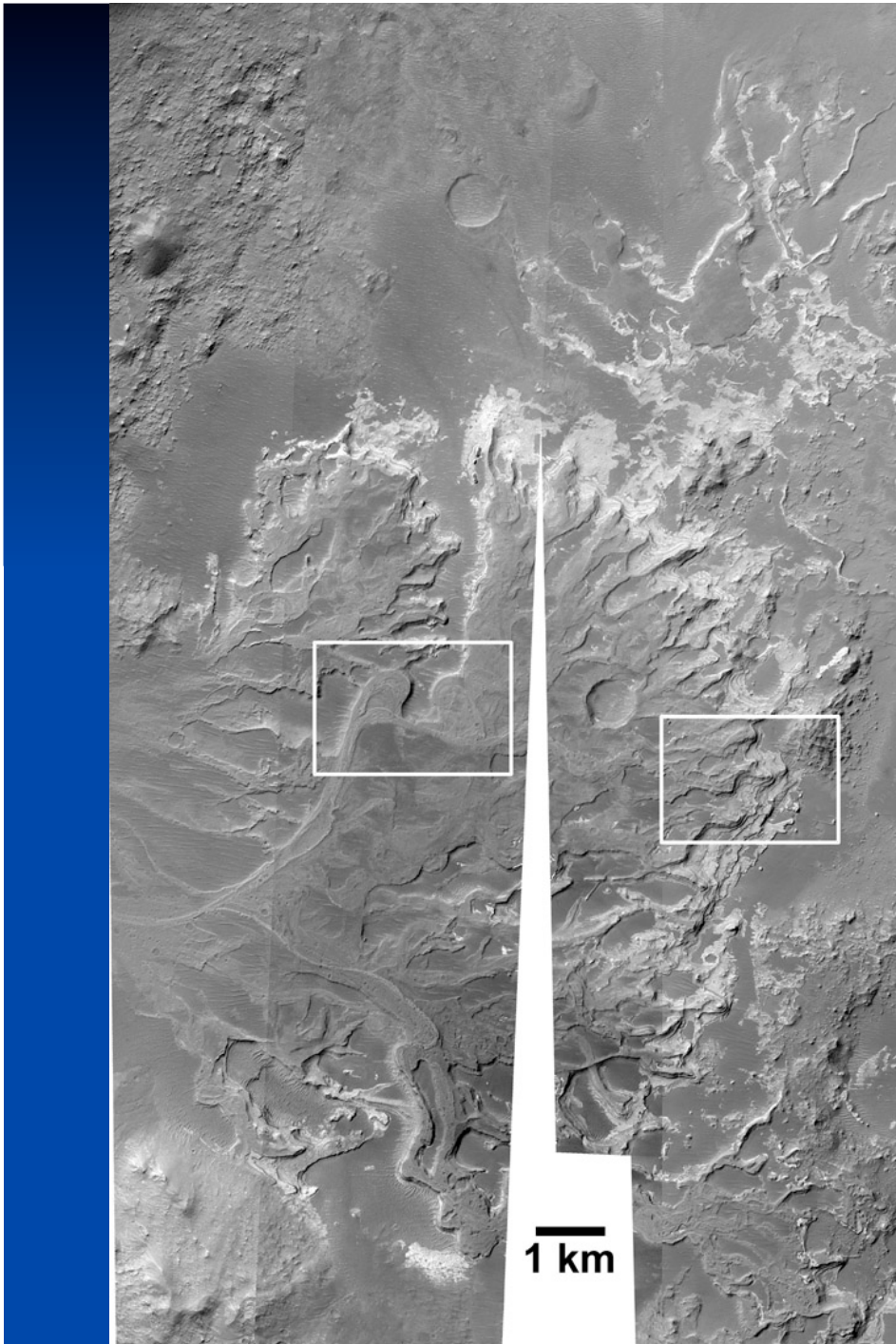
# The Holden – Parana Region





# Eberswalde HiRISE Observations

- A HiRISE image (PSP\_001336\_1560) covers most of the Eberswalde delta at a resolution of about 0.25 m/pixel
- This image reveals local concentrations of boulders exceeding 1 m in size.
- The caption for this image suggests that the boulders “were likely too coarse to have been transported by water flowing within the channels” and suggests that the boulders are weathered fragments of lithified channel sandstones.
- We suggest that some of the boulder deposits are likely to be primary depositional features and that flows through the deltaic channels may have been competent to transport these boulders.



From Moore, Howard,  
Dietrich, and Schenk, 2003

Eberswalde Crater Delta





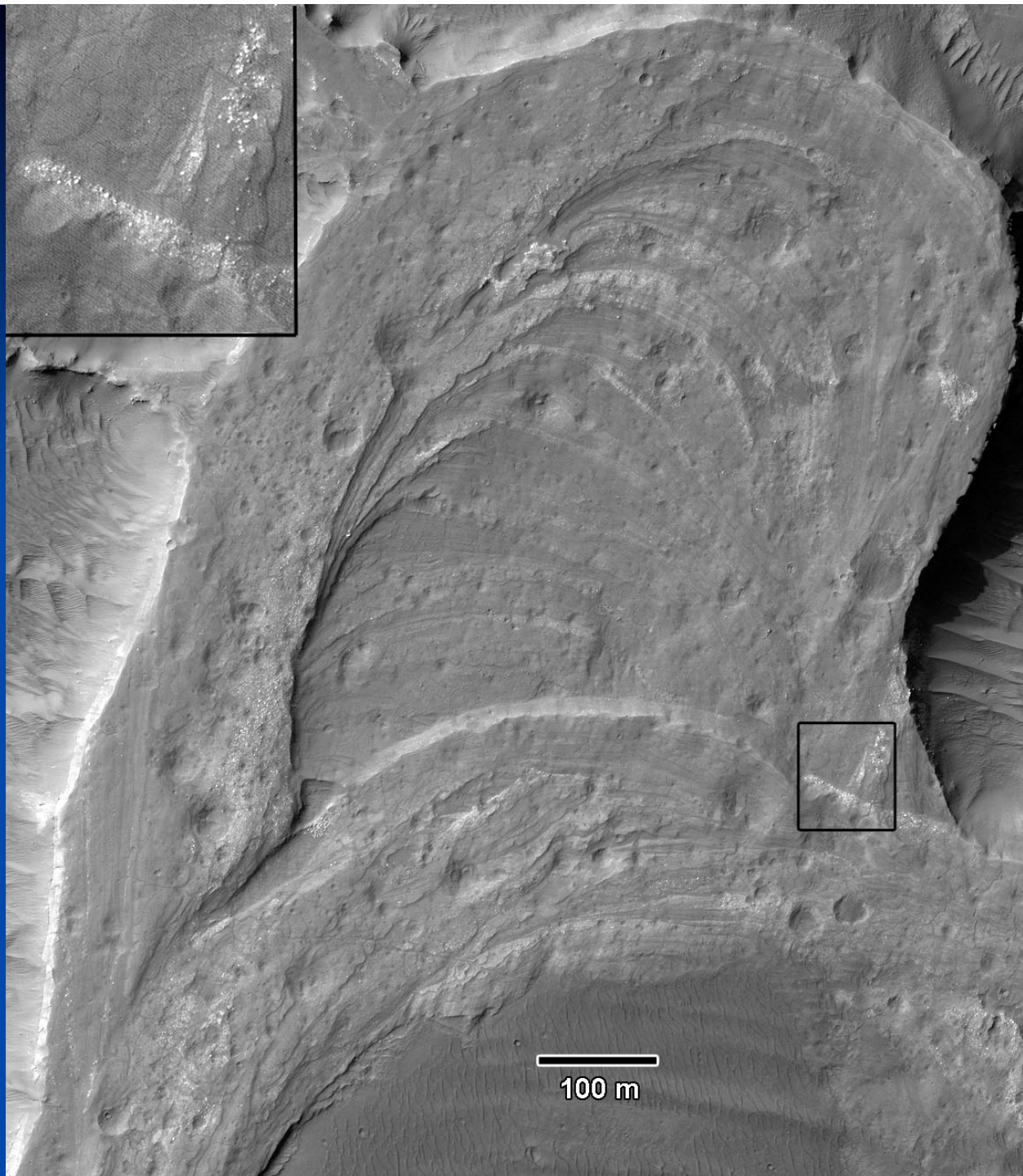
10 km

V

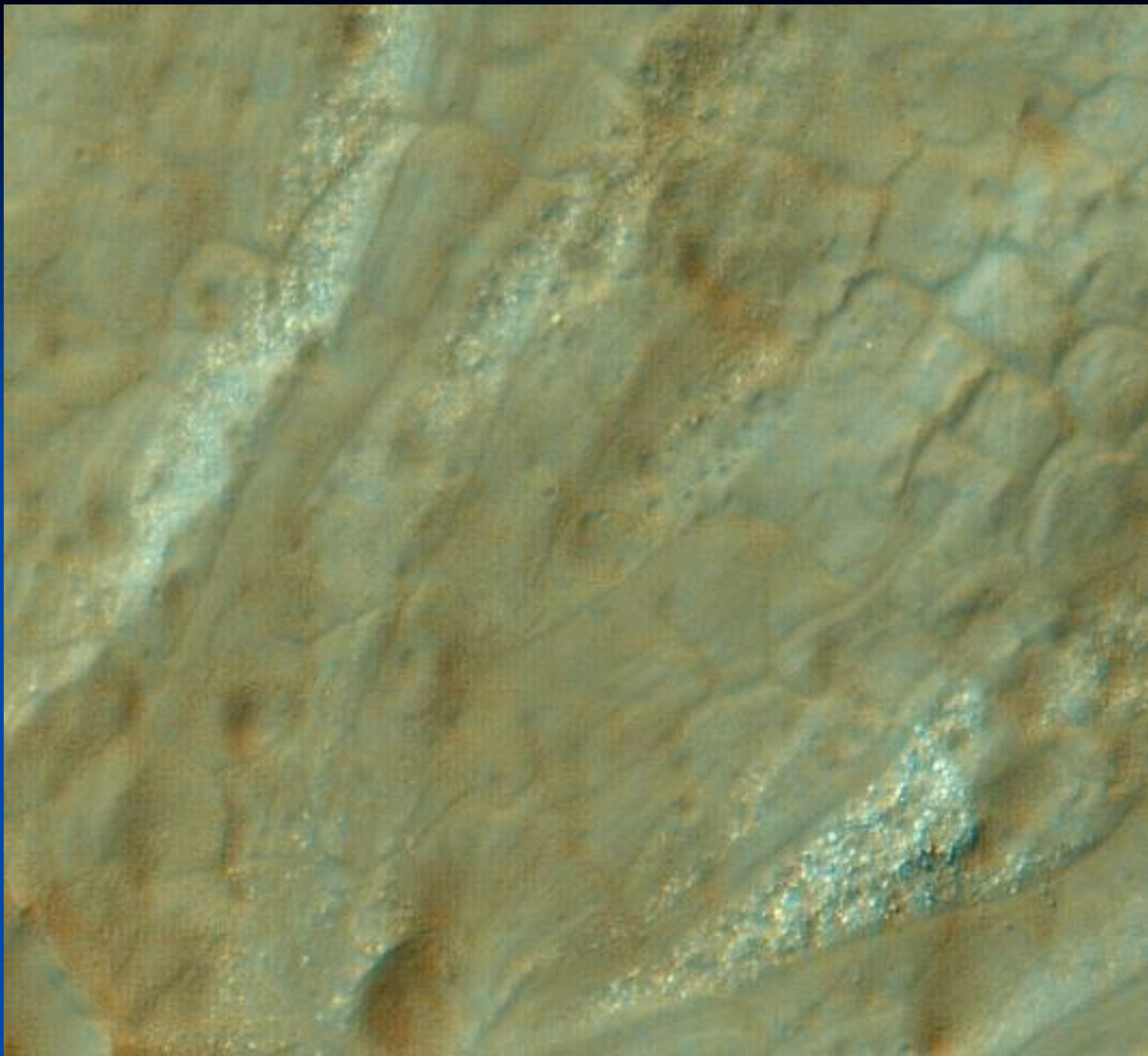


The volume of the delta  
approximately equals the  
volume of the incised  
valleys upstream









# Possible Origins of the Boulders

(Red Possibilities not examined here)

- Weathered fragments of indurated fine sediment
- Concretions
- Deposits from high-magnitude (catastrophic) floods
- Deposits from high-density flows (debris flows)
- The coarse end of the grain size distribution of sediment transported across the delta by normal fluvial flows



# Some Boulders *ARE* Weathering Products

- Some boulders are clearly released from weathering of consolidated layers in the deltaic deposit
- Generally the source bed with prismatic fracturing is visible
- Boulders are likewise prismatic
- Some boulders are >5 m
- Most have a reddish coloration



# Boulders on Delta Surface are Different than Boulders from Weathering

- Boulders occur as stringers and lenses associated with sinuous channels
- Locally boulders appear to be part of clast-supported deposit
- Source beds are not apparent
- Boulders generally less than 2 m in size
- Boulders are light-toned





# Flow and Transport through Normal Fluvial Flows?

- Channels on the delta are 50-100 m wide.
- Estimates from channel dimensions (width, meander wavelength) suggest discharges of **300-1600 m<sup>3</sup>/s.**
- The channel gradients are about 0.006
- **Can such discharges carry meter-scale boulders across such a low gradient?**

# Probably!

- What flow conditions are necessary for boulder transport?

- *Flow Transport Competence* is measured by

$$\tau^* = H S / (S_s - 1) D_{50}, \text{ where}$$

H is flow depth,  $D_{50}$  is *median* bed material grain size  
S is gradient,  $S_s$  is sediment specific gravity

- After *Parker et al. (2007)* we characterize the bankfull hydraulic geometry of streams by dimensionless depth,  $H^*$ , width  $B^*$ , and discharge,  $Q^*$ :

$$H^* = g^{1/5} H / Q,$$

$$B^* = g^{1/5} B / Q,$$

$$Q^* = Q / (g^{1/2} D_{50}^{3/2}),$$

$Q$  is bankfull discharge and  $g$  is gravity.



# Analysis

- We analyze flow competence in regard to two scenarios:
  - A **strongly bimodal size** distribution in which the meter-scale boulders are being transported across a sand or fine gravel bed. Experiments suggest the coarse fraction can be mobilized at a *Flow Transport Competence*  $\tau^* = 0.01$  (Wilcock and Kenworthy, 2001)
  - A **poorly-sorted gravel and sand mixture** with  $D_{90} = 1$  m and  $D_{50} = D_{90} / 3.5 = 0.29$  m. Experiments and field measurements suggest  $\tau^*$  in the range of 0.01 to 0.02 for  $D_{90}$  (and  $\tau^* \approx 0.04$  for  $D_{50}$ ).

# Summary of Assumptions

- Fully rough flow
- Roughness height,  $k_s = 2 D_{90}$ , that is, roughness is dominated by the boulders
- Chezy flow resistance  $C_z = 8.1 (H/k_s)^{1/6}$  (*Wong and Parker, 2006*)
- Mean flow velocity,  $V = C_z (g H S)^{1/2}$
- Channel width,  $B = 50$  m
- Gradient  $S = 0.006$
- Flow Transport Competence  $\tau^*$  is 0.04 for  $D_{50}$ , 0.01-0.02 for  $D_{90}$
- sediment specific gravity  $S_s = 2.65$
- Martian gravity,  $g = 3.8$  m/s<sup>2</sup>
- $D_{90} = 1$  m



Yellow = Assumed values  
 Green = Calculated values

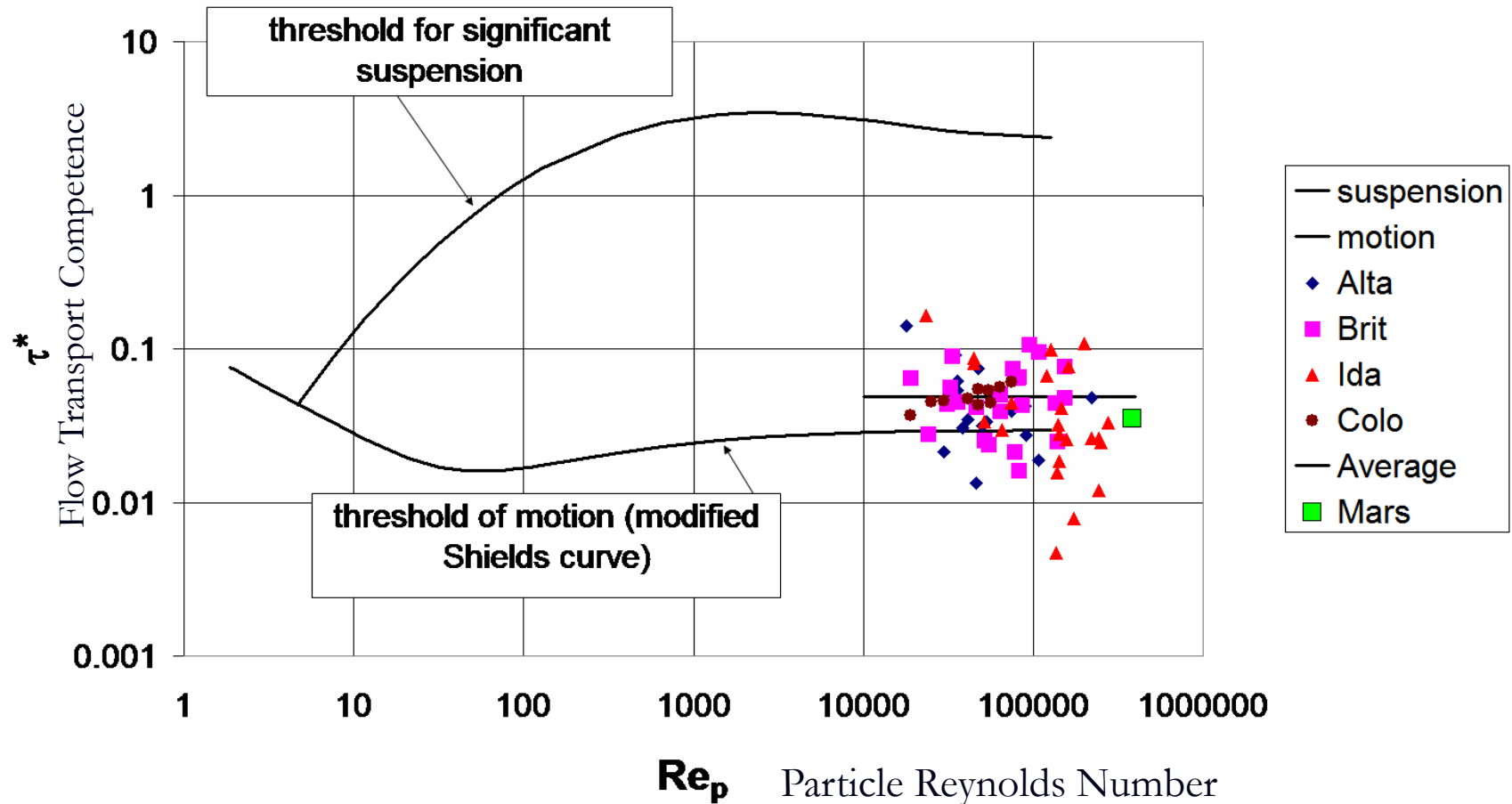
$\tau_{c90}^*$	0.01	0.015	0.04
$H$ (m)	2.75	4.13	33
$V$ (m/s)	2.14	2.81	9.37
$Q$ (m <sup>3</sup> /s)	296	580	61,820
$B/H$	18.2	12.1	6.1
$H^*$	0.37	0.42	0.52
$B^*$	6.72	5.13	3.17
$Q^*$	3457	6796	46475

$$\tau_{c90}^* = 0.01 - 0.015 \text{ Bimodal}$$

$$\tau_{c90}^* = 0.04 + \text{Unimodal}$$

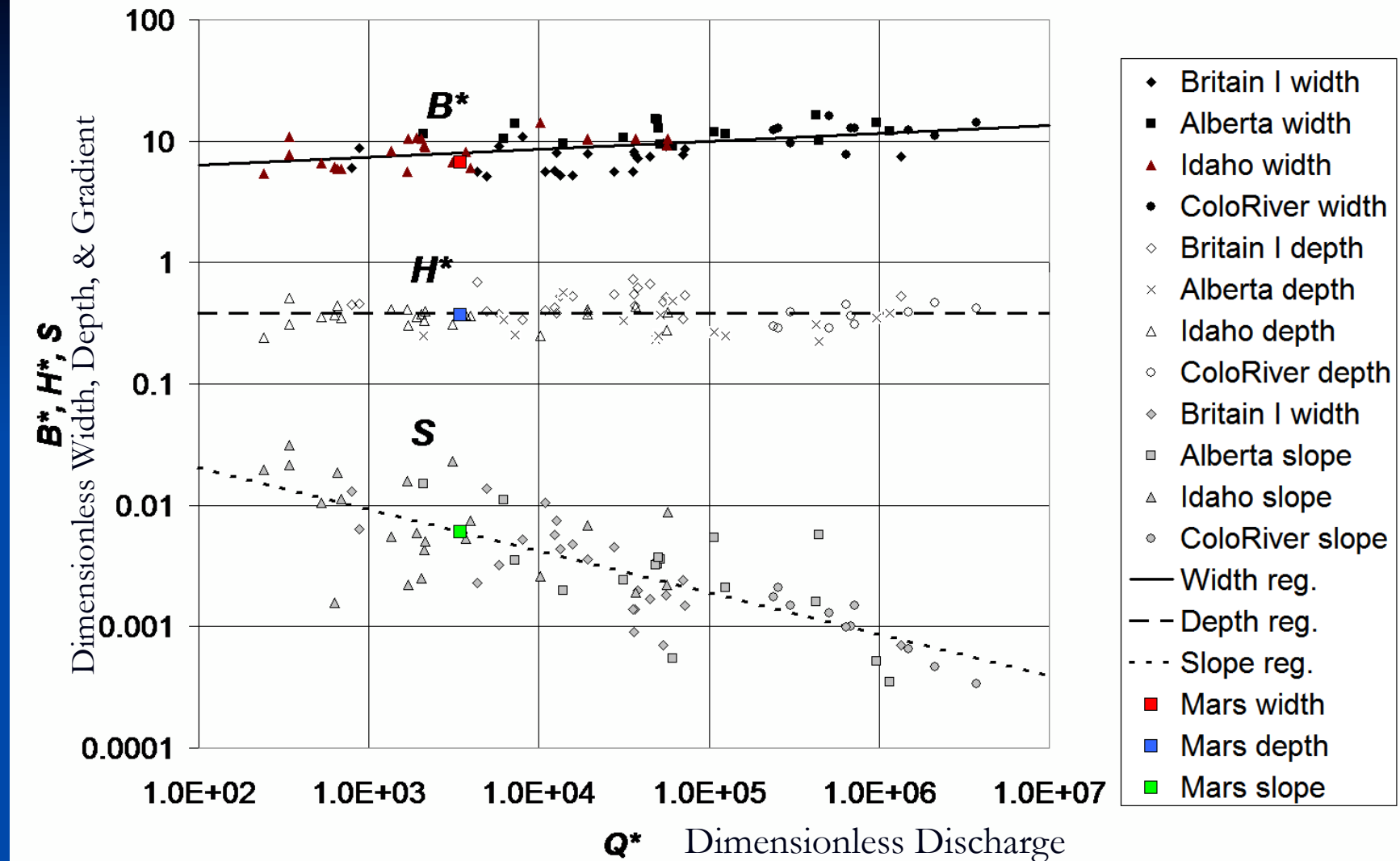
- Reasonable results for flow depth, velocity, discharge, velocity, and width-depth ratio
- A low intrinsic density of the boulders could also contribute (e.g., sediment or tephra)

# **Shields Diagram with Threshold for Motion, Threshold for Significant Suspension and Bankfull Shields Number for Gravel-bed Streams**

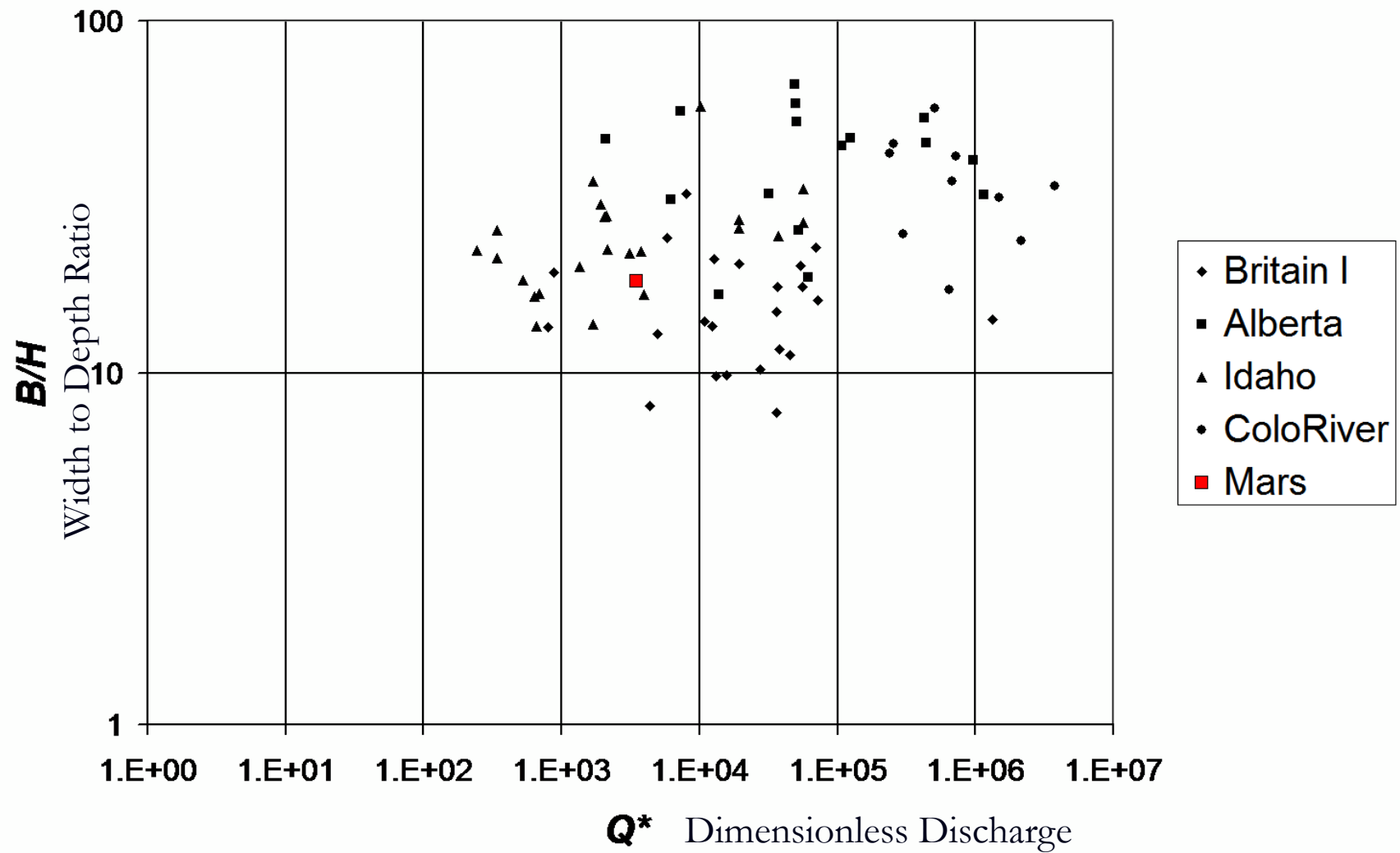


With the above assumptions and  $\tau_c^* = 0.01$  for  $D_{90}$ , a reasonable value for  $\tau_c^*$  for  $D_{50}$  is predicted.





Also for  $\tau_c^* = 0.01$  for  $D_{90}$ , the predicted dimensionless hydraulic geometry is consistent with terrestrial values

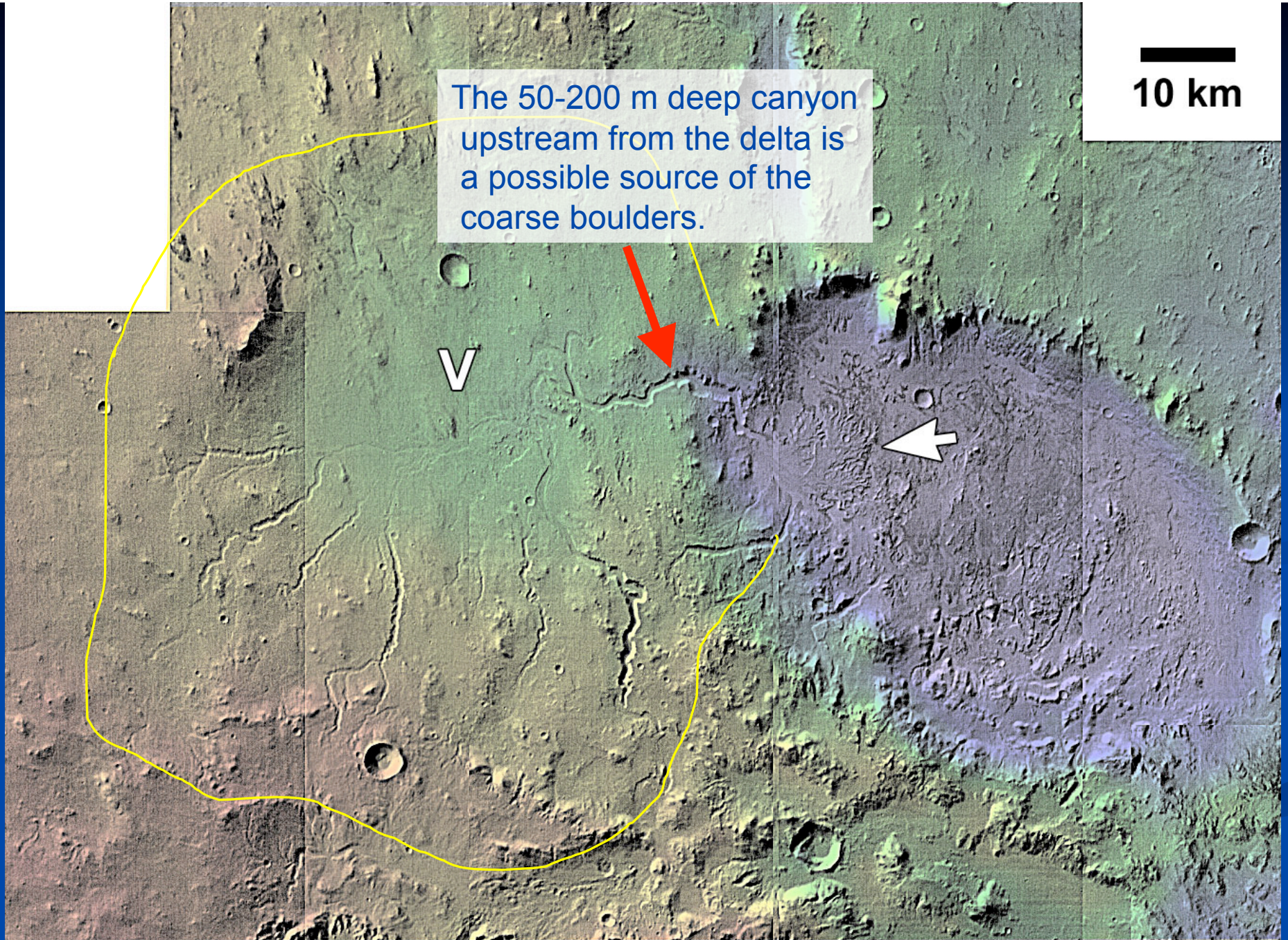


The predicted width-depth ratio is also reasonable.



10 km

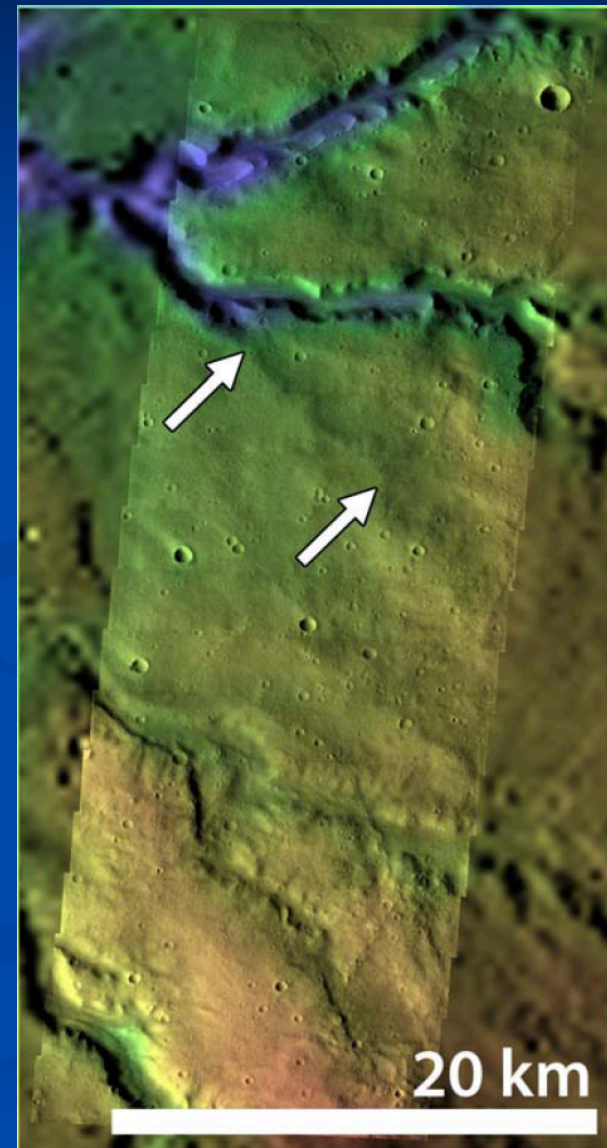
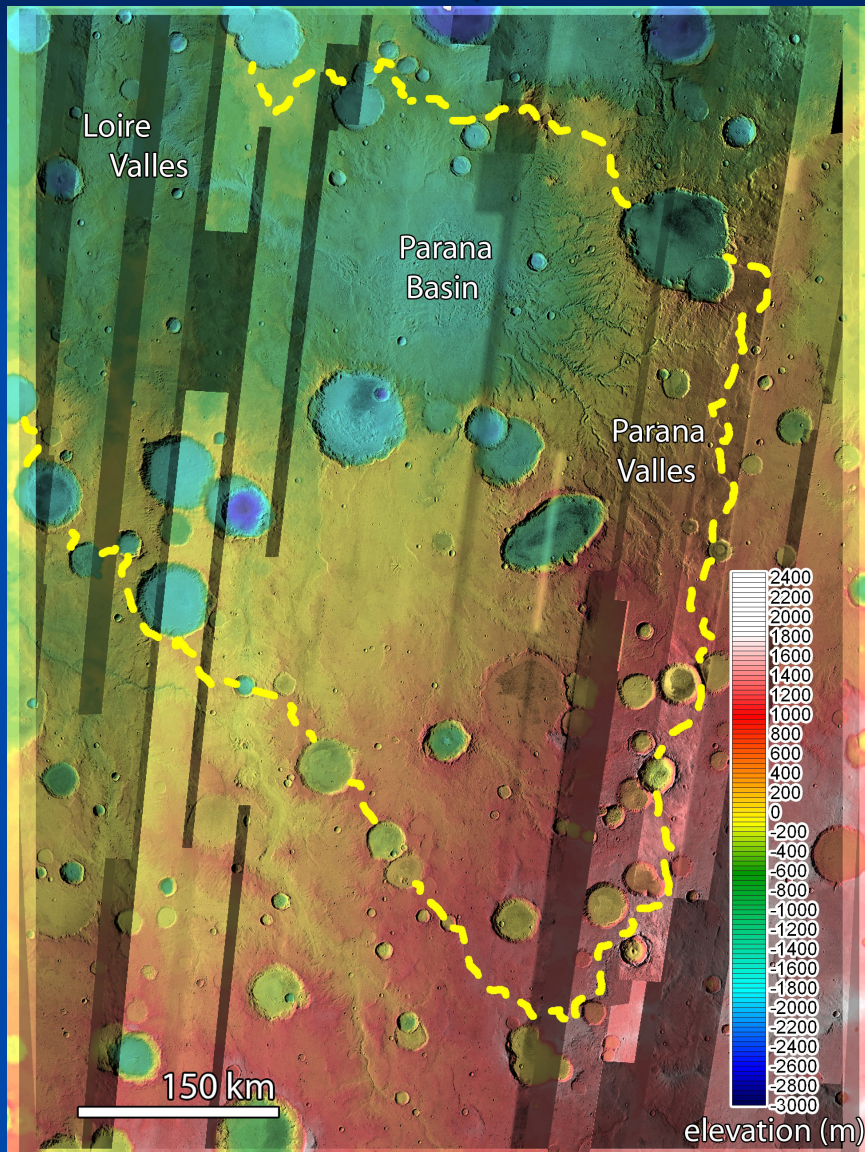
The 50-200 m deep canyon  
upstream from the delta is  
a possible source of the  
coarse boulders.





# ■ Evidence of Long Term Runoff during the N-H Transition in the Parana Basin Region

■ (Barnhart, Howard, & Moore **JGR** *in press*)



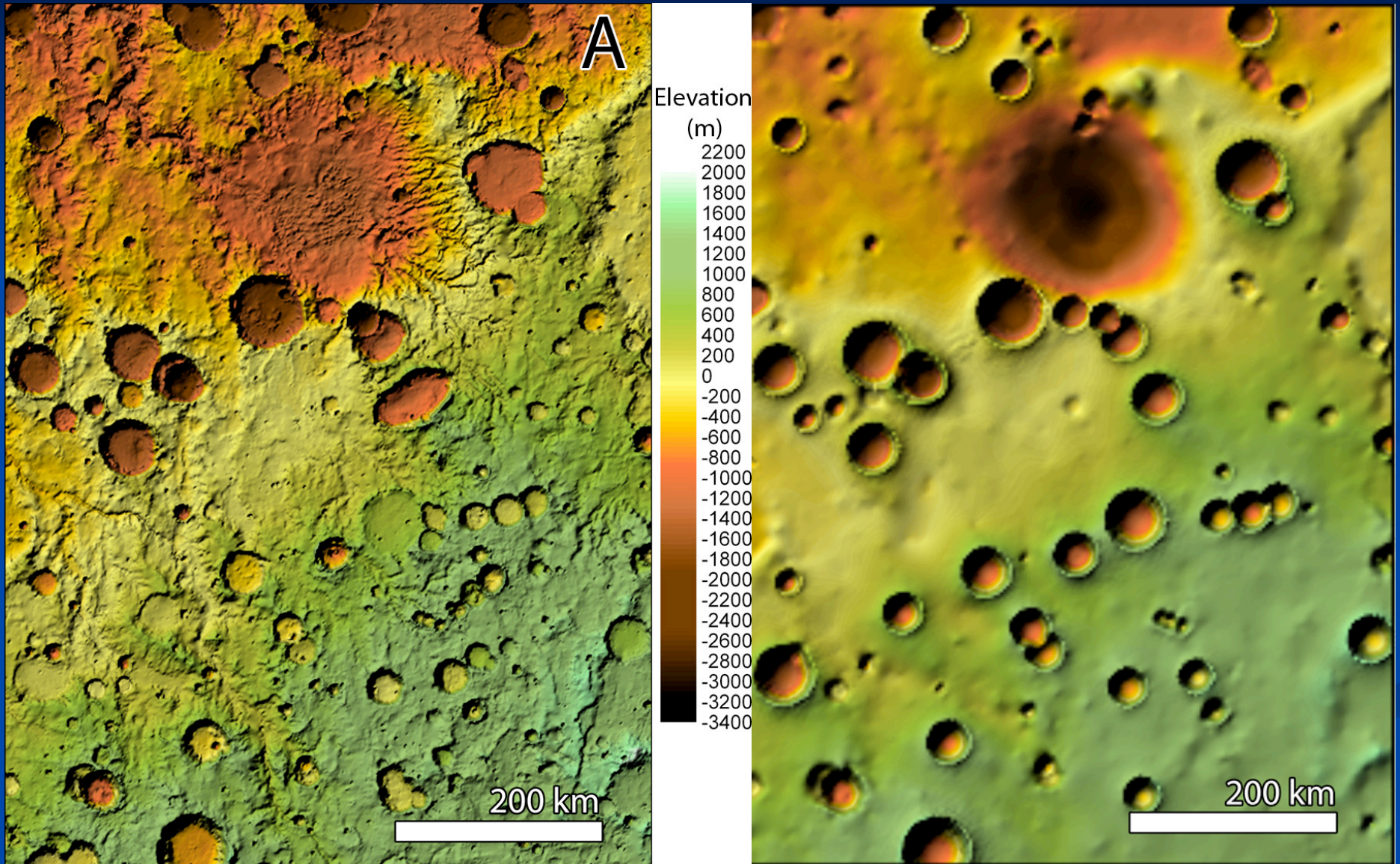


## Barnhart *et al* APPROACH

- We use a computer landform evolution model to show that Noachian-Hesperian aged, late-stage valley network formation required numerous and repeated moderate flood events rather than one or a few continuous, multiyear, deluge-style flows.
- We introduce a technique that generates an estimated “initial conditions” digital elevation model (DEM) of the Parana Valles drainage catchment (PDC) prior to valley network incision.
- We explored how variations in three classes of environmental parameters related to fluvial processes, and surface-material properties evolve the initial conditions DEM.
- Specifically, we parameterized discharge scaling, evaporation from ponded water, and the effects of an indurated surface crust.
- Each simulation run produced a model output DEM that was qualitatively and statistically compared to the actual surface DEM.

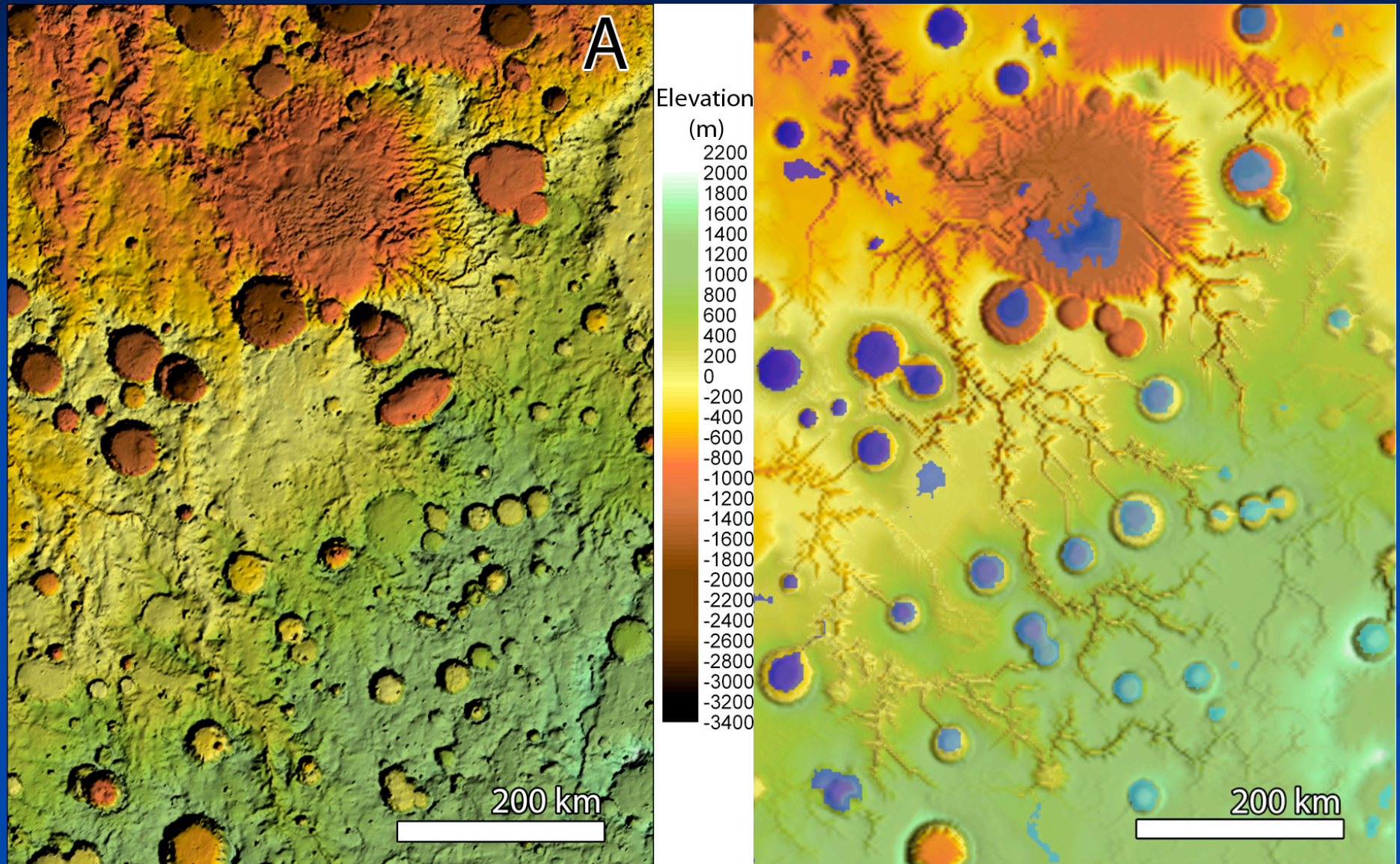


# Creating a Pre-incised Surface for Testing



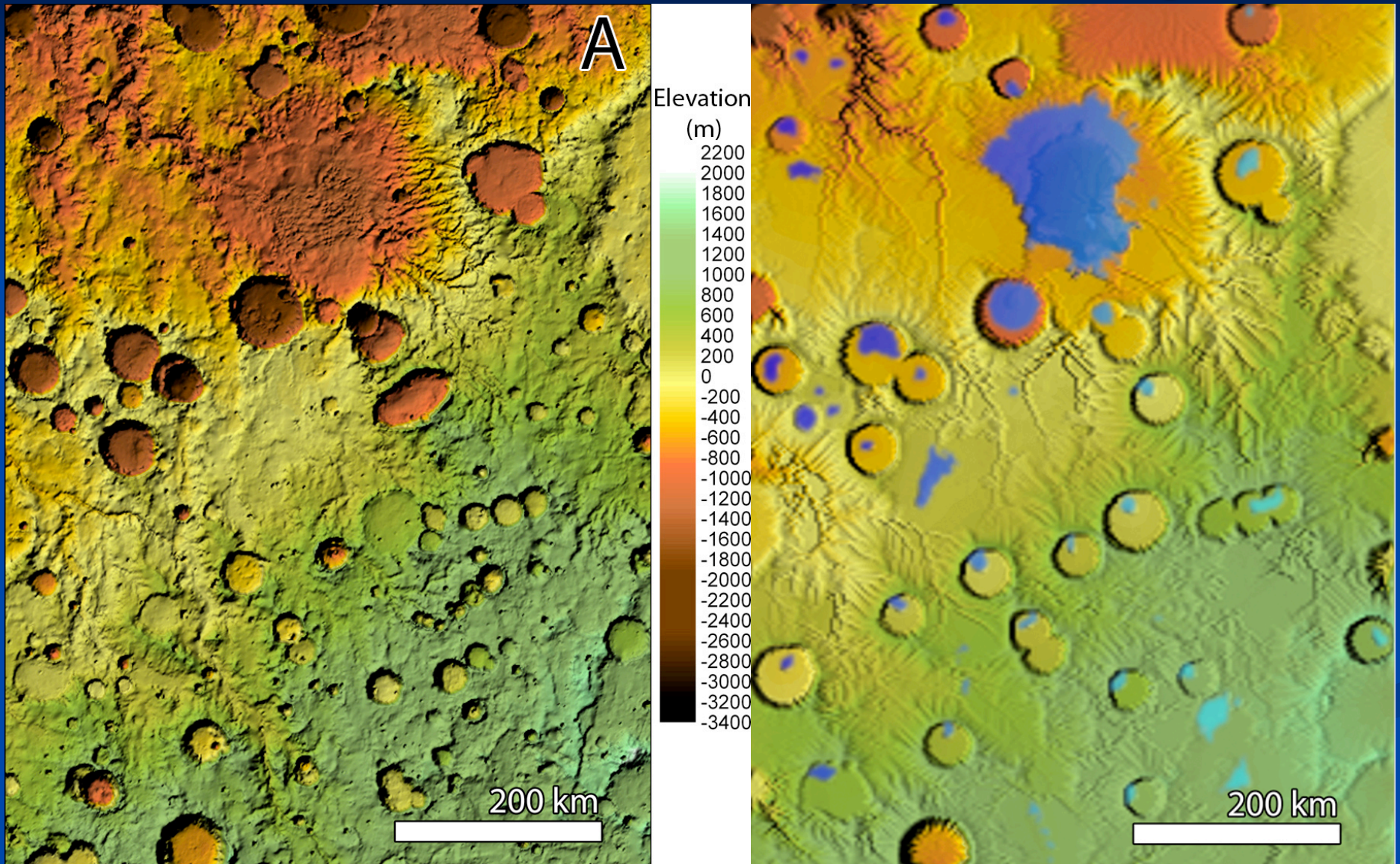


# Multi-Decade Deluge Erosion (little inter-runoff evaporation)





# At least $10^5$ Years of Arid Environment with “Mean Annual” Floods (large inter-runoff evaporation)





## CONCLUSIONS of Barnhart *et al*

- Simulations with an arid to semi-arid climate, moderate evaporation rates provide the best match to the actual surface.
- Simulated valley network formation requires periods of fluvial activity that last a minimum of  $10^3$  yrs under constant deluge-style conditions. However, craters within the PDC in deluge-style simulations overflow and generate exit breaches that cut through all crater walls.
- Longer simulations ( $10^5 - 10^6$  yrs) that modeled repeated, episodic floods with interim evaporation avoid universal crater breaching.
- The paucity of crater-rim exit breaches in the PDC and the southern highlands in general implies both that the precipitation was not continuous and that formation conditions were inconsistent with a few short-lived extreme climate excursions such as might be induced by large-scale impacts or other cataclysmic events.

The End





